Rishikesh Upadhyay

Plant Heavy Metal Stress

Physiological and Biochemical adaptations

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Physiological and Biochemical adaptations

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Rishikesh Upadhyay

To my mother, Smt. Nandakala Upadhyay (Bawni),
and
in memory of my father, Lt. Pitamber Upadhyay

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Preface

Abiotic stress is a broader conception in plant terminology. As such, only the most frequently used physiological and biochemical concepts in the day–to-day heavy metals found in nature are covered in the book. The purpose of discussion is simply to help the student and researcher learn the basic aspects of physiological, biochemical and ultra structural basis of heavy metal stress and toxicities in widely grown aquatic plants, like *Pistia* and *Spirodella*. This book is meant for research in Plant environmental stress. The beginners, especially graduate and undergraduates in Plant Science, particularly in Plant Stress Physiology, will find it a very useful guide to enlarge the horizon of their activity. Only relevant and important information is provided, adapted and revised from my own investigation on the subject carried out at Assam University, India for academic credit. A list of selected references is also provided for further reading in each chapter. I express my thanks to the editor for reading, and offering invaluable suggestions for improvement of the layout. Also, I would like to express my thanks to the publisher for using the latest liberalized printing technology.

I hope the students and researchers in plant science and environmental stress would find the book useful.

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Chapter 1

Introduction

SYNOPSIS

- Heavy metals and their affects in plants
- Physiology of heavy metals stress
- Heavy metal toxicity signaling in plants
- Biochemical and molecular insights into heavy metal toxicity
- Mechanism of heavy metal toxicity and tolerance
- Oxidative stress and antioxidant metabolism
- Heavy metal interaction in plants
- Suggested further reading

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1.1. Heavy metals and their affects in plants

Increase in environmental pollution caused by heavy metals, due to industrial and agricultural activities, has become a momentous problem in the natural world. In natural environment, modest amount of heavy metals are essential but become toxic when their concentration exceeds certain levels. Some plants are the best indicators of such hidden killers and they also develop the capacity to tolerate metabolically such toxic pollutants, including heavy metals. Aquatic ecosystem is one of the most vulnerable places for such pollution because of different effluents that may drain off finally to some water bodies subjecting the flora of the particular system to encounter toxic substances. Some aquatic plants absorb metals from air, water and soil. The uptake depends upon the soil pH, drainage status, plant species, chemical form and

location. Aquatic ecosystem acts as the receptacle for various contaminants from natural and anthropogenic sources, such as effluents from mines, smelters; excessive use of fertilizers and pesticides, and partially from aerial deposition. Although most environments are not heavily contaminated, the low levels observed nonetheless pose a high risk of heavy metal accumulation in the food chain. Also, heavy metals could be removed from the polluted soils, either by increasing the metal-accumulating ability of plants or by increasing the amount of plant biomass. For instance, where the metal content exceeds the limits of plant tolerance, plants could be treated with plant-growth-promoting rhizobacteria, as well as with increasing plant biomass for alleviating metal-polluted soils. Therefore, approaches to develop plants with reduced heavy metal uptake are important.

In natural condition, plant may be exposed during their ontogeny to a variety of stresses, of which heavy metal is known to be one of the major environmental stress affecting, tremendously the mortality of plants and low yield growing in both soil and aquatic environments. Heavy metals toxicity may be best defined as activity of a toxic ion. Compared to extended and systematic studies of heavy metal toxicity on various plants processes, very little has been done for Arsenic (As), Copper (Cu) and Zinc (Zn). Aquatic plants are one of the important components of the natural ecosystems. Despite this, major emphasis has been laid on intense genetic, biochemical, physiological and molecular studies for over 40 years, because of several traits that make it inevitable for laboratory study. Heavy metal stress imposes reduced growth, impaired metabolism, and affects various others plant processes. Though it is well documented in certain literatures that heavy metal stress affects various plant processes but very little is known about the biochemical and molecular alterations that entail the detrimental effects to the heavy metals responses of aquatic plants.

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Heavy metal toxicity is an important abiotic stress. It induces oxidative damages in to both aquatic and terrestrial plants besides affecting antioxidant systems, altering different physiological and biochemical processes that cause significant losses in productivity. Imposition of heavy metal stress may increase

Short forms

AOS	-	Active Oxygen Species
ROS	–	Reactive Oxygen Species
APX	–	Ascorbate Peroxidase
BSA	–	Bovine Serum Albumin
NBT	–	Nitroblue Tetrazolium
Car	–	Carotenoids
Chl	–	Chlorophyll
^{o}C	–	Centigrade
CAT	–	Catalase
SOD	–	Superoxide Dismutase
$RO^{\cdot}$	–	Alkoxyl Radical
DHA	-	Dehydroascorbic acid
Cm.	–	Centimeter
et al.,	–	et alie (and others)
EDTA	–	Ethylene Diamine Tetra Acetic Acid
Fig.	–	Figure
DNA	-	Deoxyribo nucleic acid
PCR	-	Polymerase chain reaction
FW	–	Fresh weight
DW	–	Dry weight
POX	–	Peroxidase
GR	-	Glutathione Reductase
GSSG	-	Glutathione (oxidise)
g.	-	Gram
LOX	-	Lipoxygenase

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H_2O_2	-	Total Peroxide
KOH	-	Potassium Hydroxide
M	-	Molarity
min.	-	Minute
MDA	-	Malondialdehyde
MDHAR	-	Monodehydroascorbate Reductase
NBT	-	Nitroblue Tetrazolium
nm	-	Nanometer
NADPH	-	Nicotinamide Adenine Dinucleotide Phosphate (Reduced)
$^{\cdot}OH$	-	Hydroxyl Radical
$^1O_2$	-	Singlet Oxygen
Cu	-	Copper
$O^{-\cdot}_2$	-	Superoxide Radical
%	-	Percentage
r.p.m	-	Revolution Per Minute
TCA	-	Trichloro Acetic Acid
TBA	-	Thiobarbituric Acid
GSH	-	Glutathione (reduce)
TBARS	-	Thiobarbituric acid reactive substance
BHT	-	Butylated Hydroxy Toulene
ml	–	Millilitre
mM	–	Millimolar
µ	–	Micron
h	-	Hour
W	–	Watt
wt	–	Weight
K	–	Potassium
Ca	–	Calcium
Na_2CO_3	–	Sodium carbonate
N	–	Normality

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KNO_3	–	Potassium nitrate
NEDH	–	N-naphthalene diamine hydrochloride
As	-	Arsenic
AS (III)	-	Arsenite
As (V)	-	Arsenate
Dw	-	dry weight
ANOVA	-	Analysis of Variance
SE	-	Standard errors
AsA	-	Ascorbate
Zn	-	Zinc

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